Sample Containment Technology for Mars Sample Return

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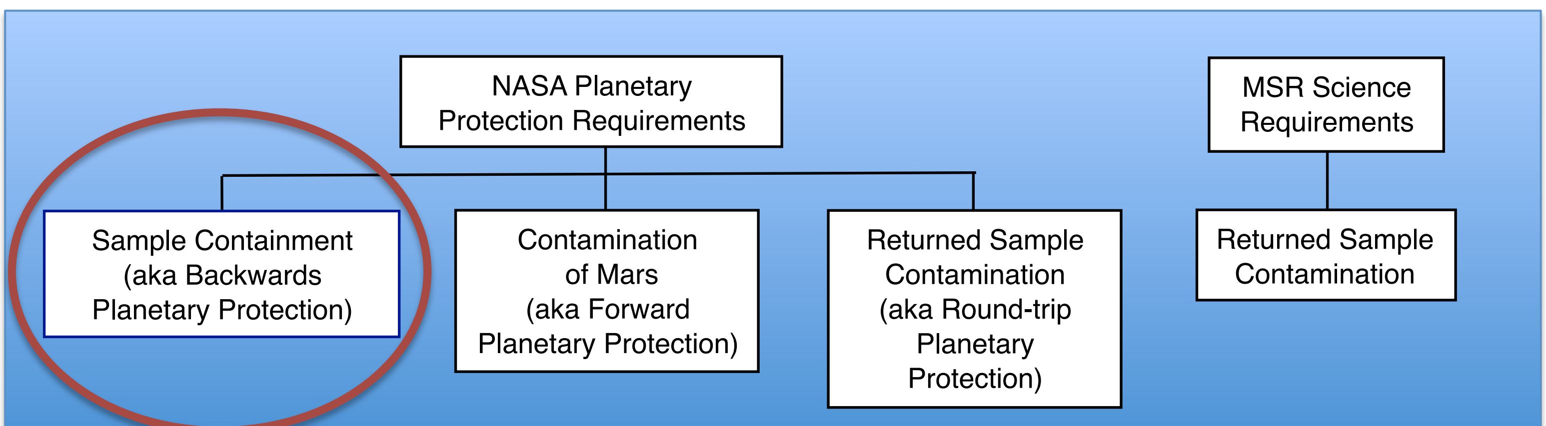
Introduction

- Focus on potential first Mars Sample Return
- "Sample containment" requirements
- Technology needs & options



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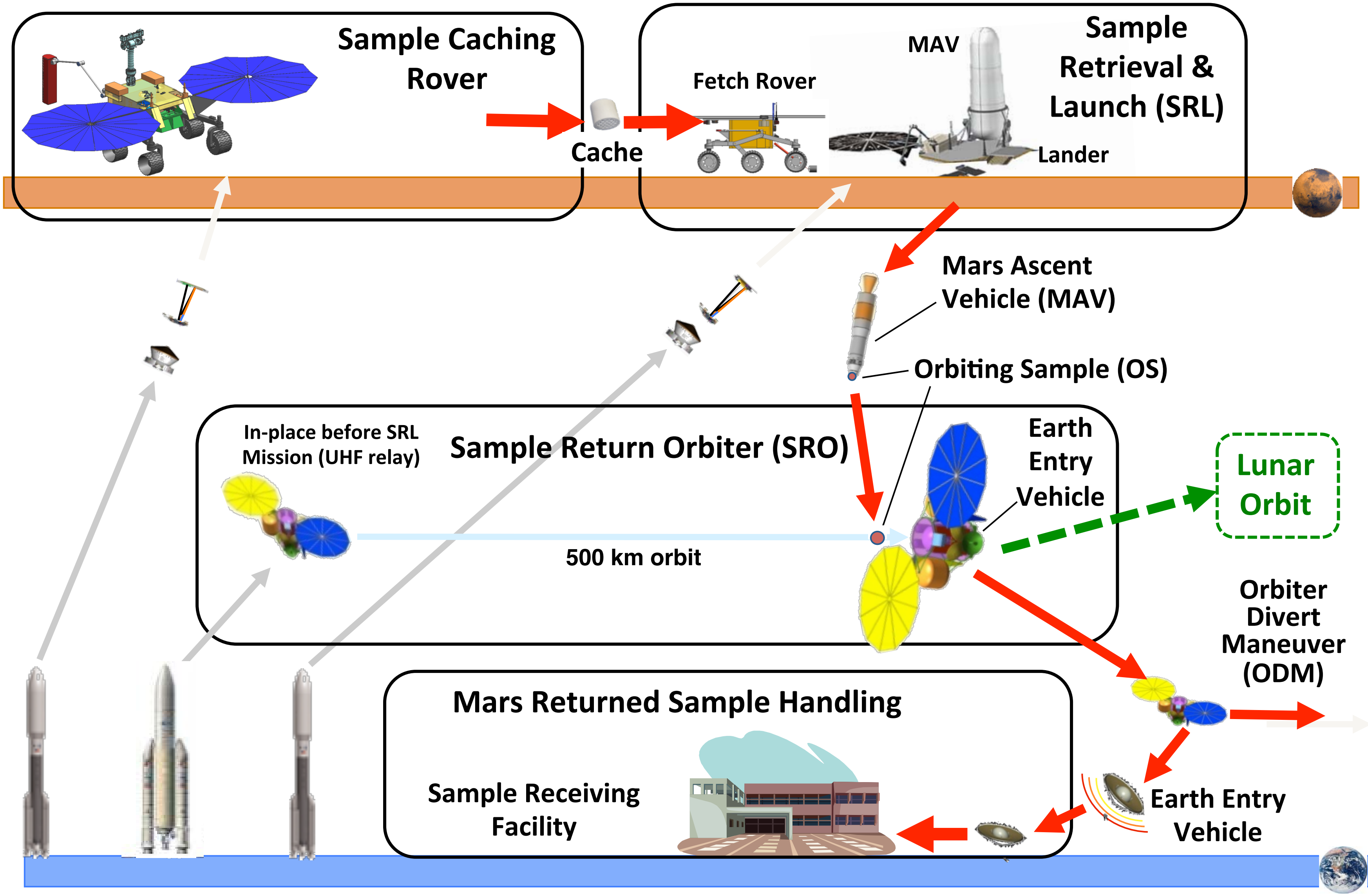
Background

- Mars Sample Return (MSR) has been designated as highest priority among flagship planetary science mission options by the U.S. National Research Council Decadal Survey (2011).
- The Science Definition Team for NASA's proposed Mars 2020 rover mission identified, as one of that mission's principal objectives, caching of carefully selected samples on the Mars surface for possible delivery to Earth by a subsequent mission (or set of missions).
- The Mars Program has begun conceptual studies of how to bring home the cached samples and preliminary work on enabling technologies.
- We've been working on MSR concepts for forty years, but implementation has been impeded by several major technical challenges, including:
  - Launching the samples from the surface of Mars
  - Rendezvousing with and capturing the sample container in Mars orbit
  - Providing robust sample containment
  - Providing a robust Earth entry/descent/landing capability consistent with the sample containment requirements.

Sample Containment Requirements

- Top level American and European science panels have considered the potential risk to the Earth's biosphere represented by Mars sample return. Conclusions:
  - The risk is very low but **"not zero"**.
  - "Samples returned from Mars by spacecraft should be **contained and treated as though potentially hazardous until proven otherwise**. No uncontained martian materials, including spacecraft surfaces that have been exposed to the martian environment, should be returned to Earth unless sterilized."
- This has been translated into NASA procedural requirements (NPR 8020.12)
  - "Unless the sample to be returned is subjected to an accepted, approved, sterilization process, the sample container must be sealed after sample acquisition, and a **redundant, fail-safe containment** with a method for verification of its operation before Earth-return shall be required."
  - "The mission and the spacecraft design shall provide a method to "**break the chain of contact" (BTC)** with Mars. No uncontained hardware that contacted Mars, directly or indirectly, may be returned to Earth unless sterilized."
- The NASA Planetary Protection Officer has provided a draft "containment assurance" requirement for the first MSR mission (the focus here):
  - **<10^{-6} probability of inadvertent release of a single unsterilized Mars particle [> 50 nm] to the Earth's biosphere**

MSR Campaign Concept



Sample Containment Elements

Break-the-chain of contact with Mars

- Sample container sealing & separation
- Sealing verification, leak detection
- Dust mitigation, capture hardware jettison
- SRO divert

Maintaining containment during return & Earth entry/landing/handling

- Delivery to Earth entry corridor
  - Navigation reliability
  - Spacecraft reliability
- Earth Entry Vehicle (EEV)
  - Aerodynamics & structural integrity
  - Thermal protection
  - Impact protection
- Meteoroid protection
- Location, recovery, transport

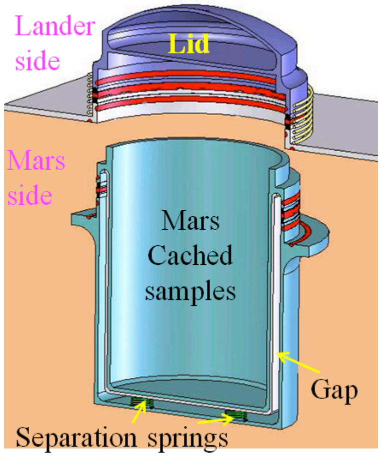
→ Clean, sealed sample container delivered to containment facility on Earth with samples, container, and seals protected from entry heating, landing shock, and any other risk.

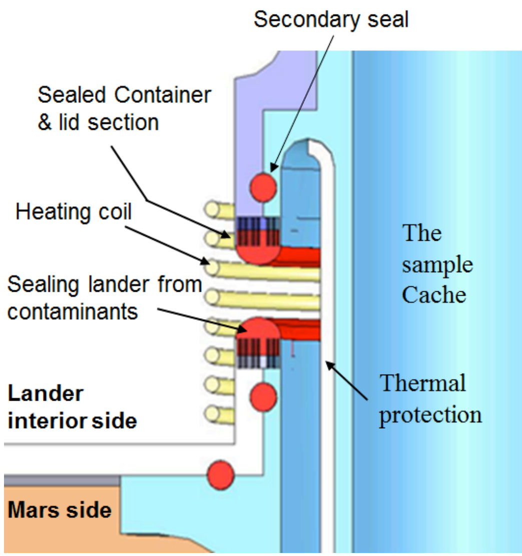
Break-the-Chain Options

- Several options under consideration
- BTC on Mars surface or during ascent
  - Clean OS placed in orbit
  - Complex sealing/separation system on SRL and/or MAV
  - Avoid carrying Mars dust to orbit on MAV
- BTC in Mars orbit
  - Dusty OS placed in orbit
  - Complex containerization/sealing/separation system on SRO

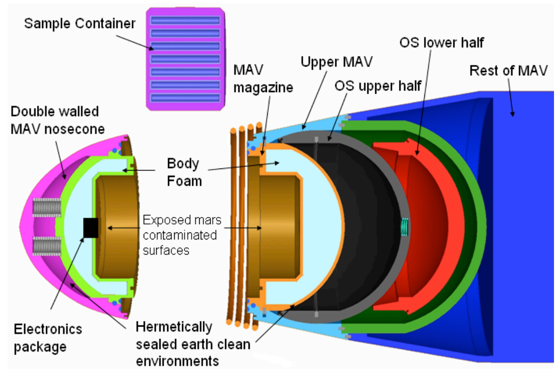
    or
  - Sealing of OS before launch plus exterior sterilization in orbit
  - Deal with Mars dust brought to orbit on MAV or OS
- Combinations

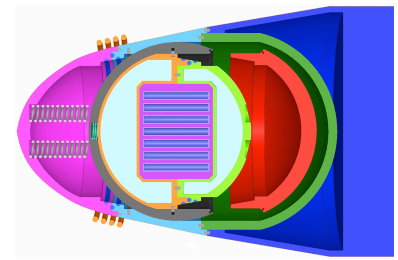
Examples of BTC during Loading into MAV

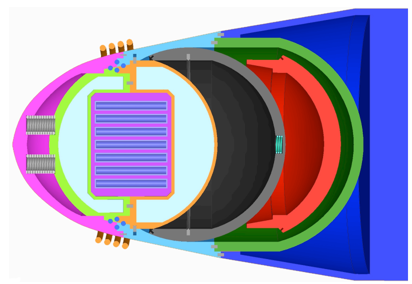


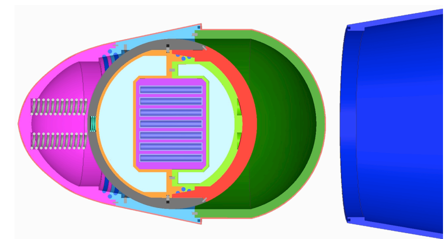


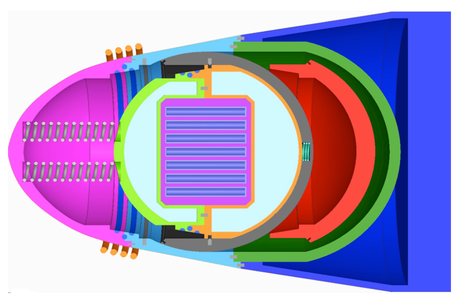
Sealing & separation using brazing

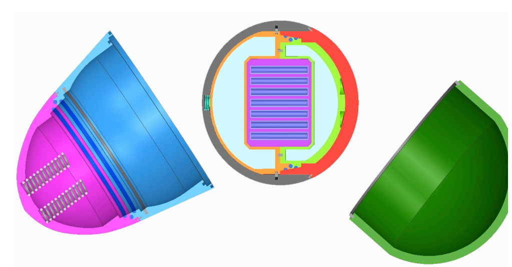






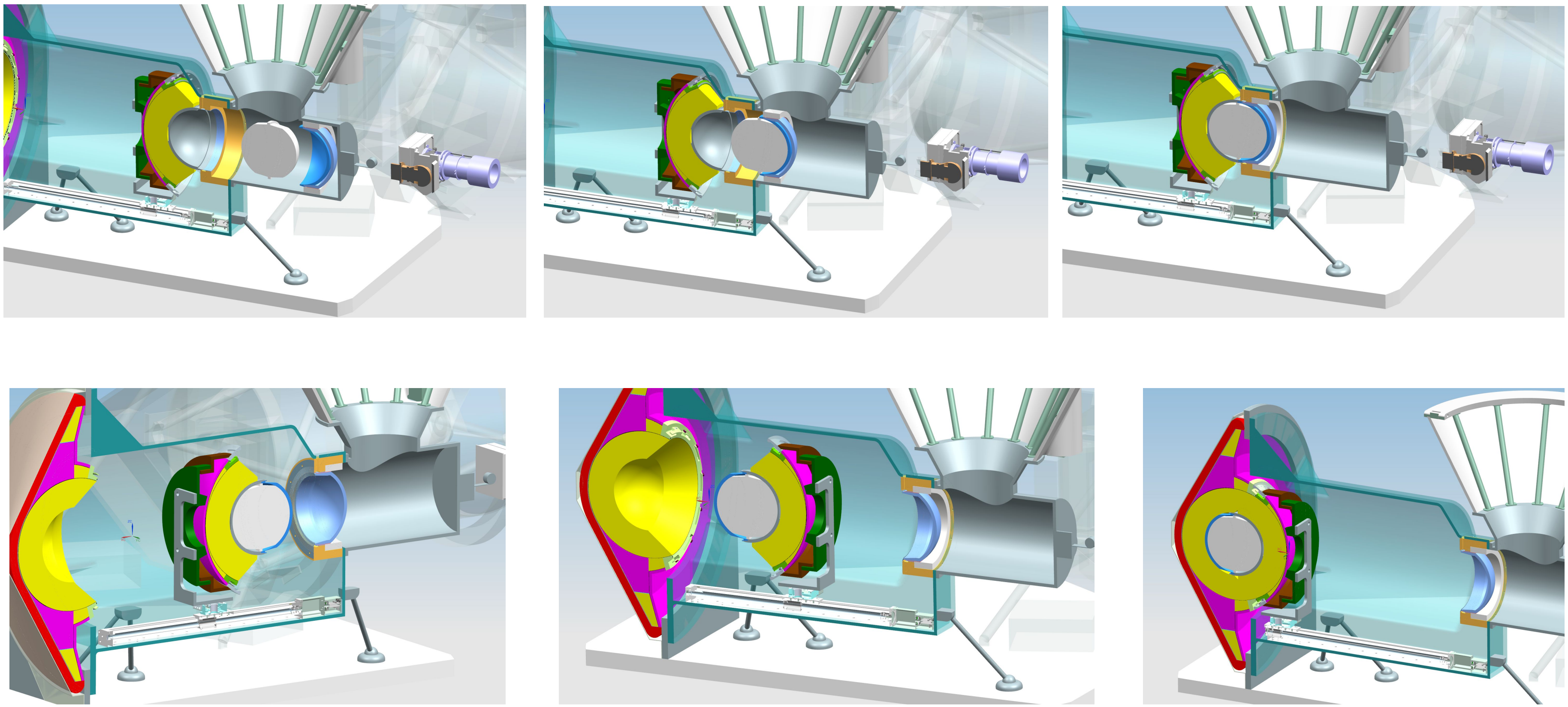






Example of BTC after Capture by SRO

Investigating sealing and separation of a double lid using either brazing or explosive welding



Additional BTC Considerations

- Verification & monitoring
  - Evaluating leak check & seal examination methods
- For BTC on Mars surface or during ascent
  - Avoid carrying Mars dust to orbit on MAV
    - MAV surface treatment
    - Shed layers during ascent
- For BTC in Mars orbit
  - Deal with Mars dust brought to orbit on MAV or OS
    - Analysis of dust encounter probabilities
    - Dust barrier covering EEV (may double as meteoroid shield)
    - Investigation of potential sterilization by UV and cold

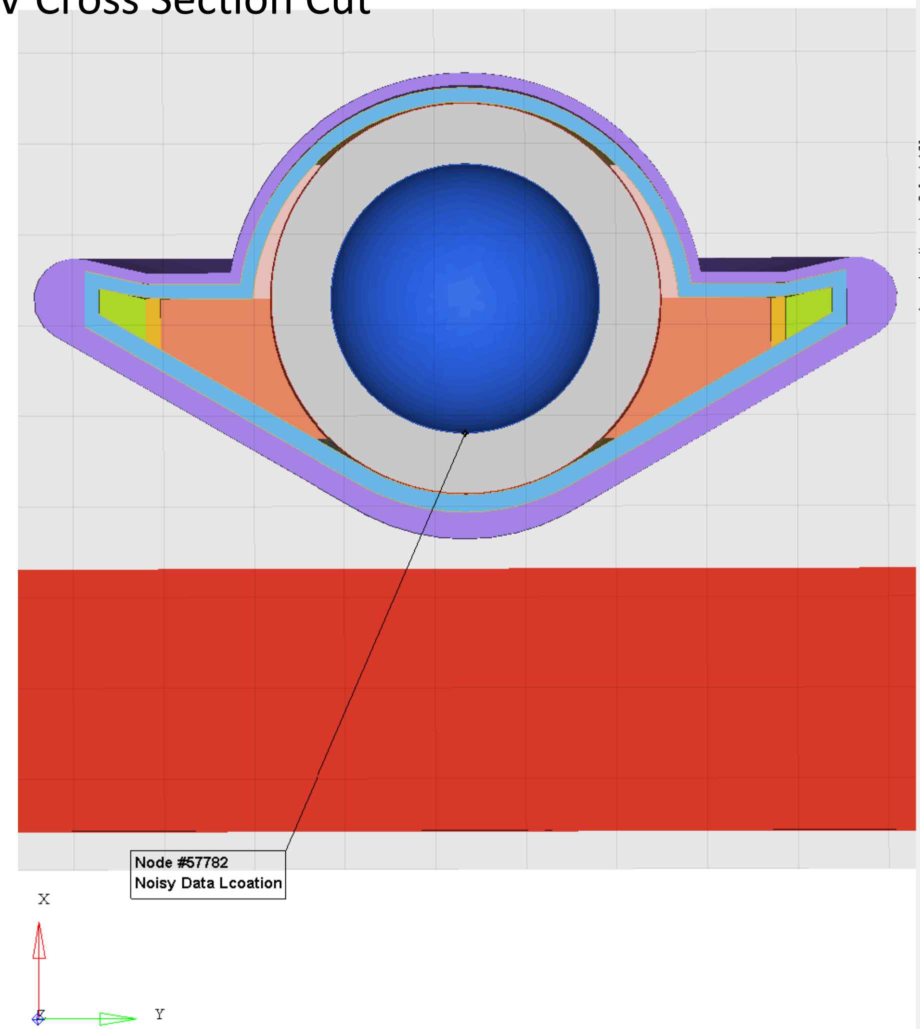
Maintaining Containment

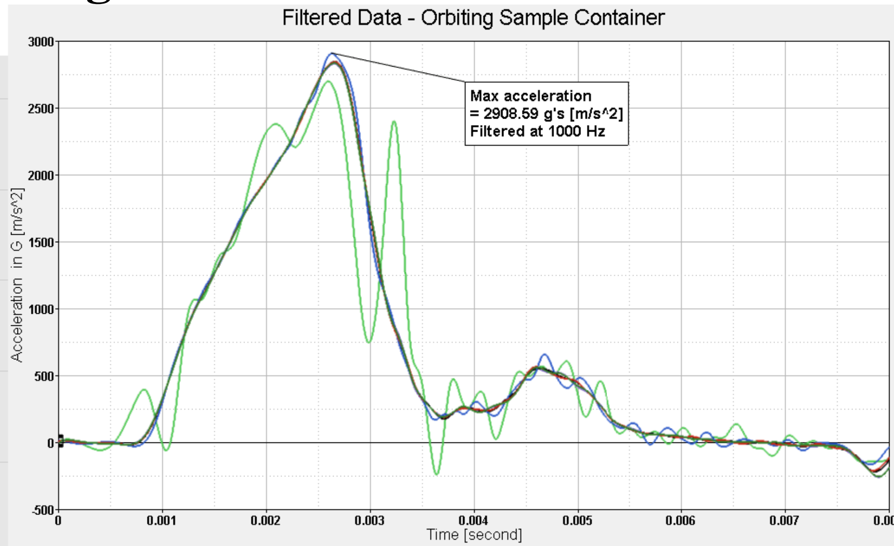
- Developing a new Earth Entry Vehicle concept: verifiably robust
  - No parachute, impacts at testable terminal velocity
  - Thermal protection heritage from recent planetary missions with large margins
  - Strong emphasis on spacecraft and navigation reliability, with upgrades to systems and processes as needed to meet requirements
- Shielding all elements against worst case meteoroid flux and damage estimates
- Targeted for well-controlled landing range with minimal hard surfaces
- Recent alternative: human-assist

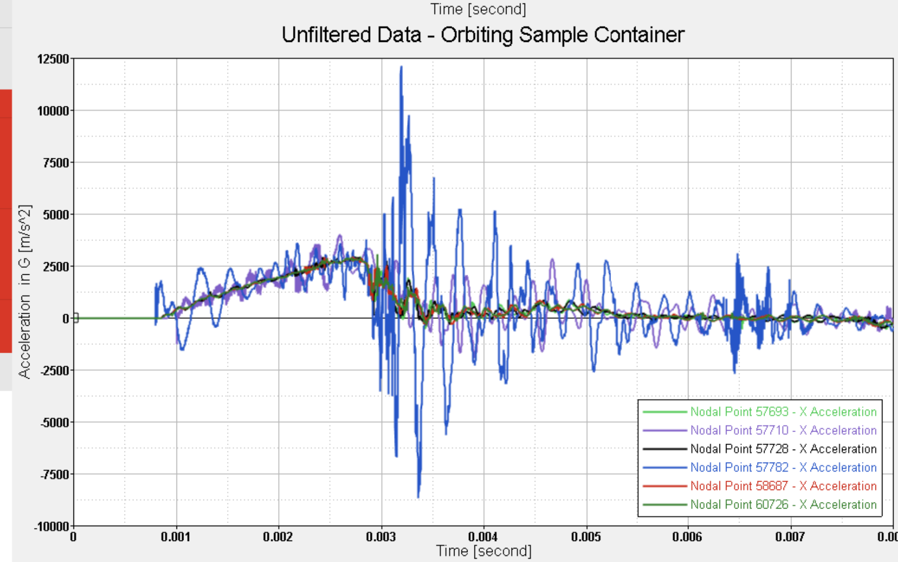
EEV Finite Element Impact Analysis

Rigid Surface using Titanium OS

EEV Cross Section Cut



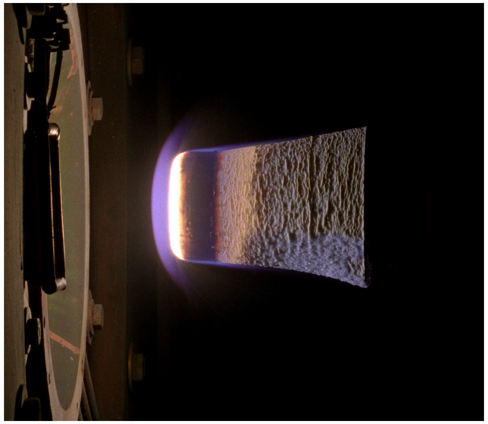


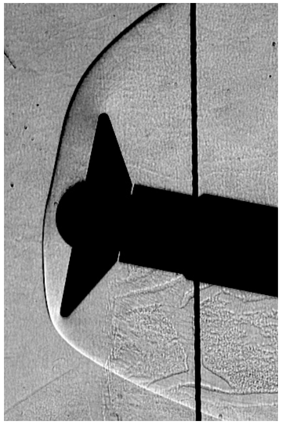


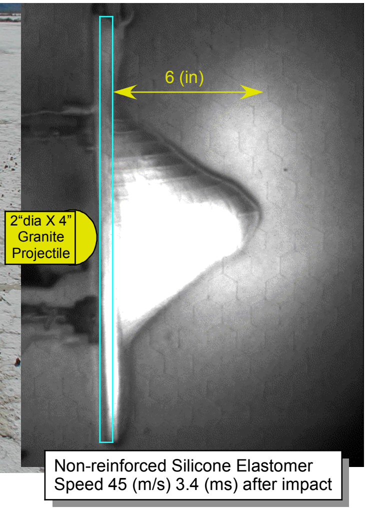
Negligible OS damage

Technology Development 1999-2005

- Container sealing
  - Low TRL work on brazing and explosive welding
- Soft container
  - Gun tests of candidate materials
  - Sealing methods development
- Earth entry vehicle
  - Arc jet testing of TPS
  - CFD analysis and wind tunnel testing of self-righting capability
  - Impact analysis and drop testing
- Meteoroid protection
  - Advanced shielding concepts
  - Hit or breach detection







Ongoing Technology Development

Working toward downselect of scenarios and modalities

- Proof-of-concept technology tasks
  - Sealing modalities
    - Brazing
    - Explosive welding
    - Bagging
    - O-rings and other soft seals
  - Pyrotechnic surface sterilization*
- Preliminary feasibility assessment
  - Robust sample container
  - OS sterilization* before capture – laser heating
  - OS sterilization* chamber on SRO
    - Hot gas generator
    - Plasma
- Supporting analyses
  - Dust issues and mitigation
  - MMOD threat
  - Risk quantification methods

*There are no currently approved techniques for sterilizing Mars material.

Relevance to Human Mars Missions

- Containerization and dust mitigation concepts being developed for robotic MSR may be adaptable to:
  - Robotically acquiring samples to be characterized at a Mars base prior to human exploration of the sampling site
  - Returning questionable samples to Earth for detailed study
- A comprehensive study of methods to be used to provide these functions is needed.